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DEPARTMENT OF
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NEW BRUNSWICK

CANADA



Laboratory Report on Preparation of
SPECIMENS FOR DURABILITY OF
PORTLAND CEMENT/FLY ASH CONCRETE
PHASE IV
for the
DEPARTMENT OF ENERGY, MINES AND RESOURCES

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Laboratory Report

1. Introduction

The Department of Civil Engineering of the University of New Brunswick was awarded contracts in 1978, 1979, 1980 and 1981, by the Department of Supply and Services to prepare large concrete specimens that are to be used by the Department of Energy, Mines and Resources (EMR) in durability studies at the U.S. Corps of Engineer's salt water exposure site at Treat Island, Maine. Copies of these reports can be obtained from EMR in Ottawa. The first two reports cover specimens containing Type 10 and 50 cement with varying percentages of cement replacement with slag and fly ash and with aggregate from the Blagdon Pit. The first report also included the use of high range water-reducers. The third report covered the use of slag as a replacement for Type 10 and Type 50 cements in semi-lightweight concrete made from expanded shale aggregates. This fourth report covers the use of Type 10 and Type 50 cement in concrete made from sand from the Blagdon Pit and limestone coarse aggregate from the Brookville Pit.

The contract dated May 22, 1981 was subsequently revised prior to work starting. The revised contract is in Appendix A. Amendments were to clarify the contract with no changes in the amount of work required.

The contract covered three water-cement ratios (Series J, K and L), two types of Portland cements and with and without the replacement of cement with fly ash. All mixes contained an air-entraining agent.

The Canadian Standards Association Standard A23.1 - 1973 on "Concrete Materials and Methods of Concrete Construction" and A23.2 - 1973 "Methods of Test for Concrete " were followed, unless otherwise noted. As this was part of a continuing program and the first part was done before the 1977 issue of the standard was available, it was decided to retain the same standards for this work. Also the Imperial units were used for a similar reason and for convenience in reporting results to the U.S. Corps of Engineers who look after the exposure site.

2. Materials

(a) Cement

The cement was supplied by Canada Cement Lafarge Ltd. and was delivered in paper bags. All cement was free of lumps and was free flowing.

(b) Fly Ash

The fly ash was delivered in metal drums from the Lingan, N.S. power plant.

(c) Air-entraining Agent

The air-entraining agent was a sulphonated hydrocarbon type AEA supplied by W. R. Grant.

(d) Aggregates

The sand (#4 minus) was from the Blagdon Pit. The coarse aggregate was from the Brookville Pit in Saint John and is a dolomitic limestone. The aggregates were delivered in two sizes (#4 to $\frac{1}{2}$ and $\frac{1}{2}$ to $\frac{3}{4}$) to prevent segregation. The results of tests carried out on the aggregates are listed in Appendix B. All aggregates were delivered about a month prior to the start of mixing.

3. Batching and Mixing to Facilitate Handling.

To facilitate handling of the various ingredients and to enable adjustments to be made to the mix the ingredients were batched in two lots of equal size. To the skip was added one half the coarse aggregates, one half the cements and one half the fine aggregates. The mixer was started and the contents of the skip dumped into the mixer. Immediately prior to charging the mixer one half of the air-entraining admixture was added to one half of the water and stirred. The sequence was such that the

mixer was started and the contents of the skip added to the mixer simultaneously with the addition of the water and air-entraining admixture.

Mixing was continued for two minutes at which time the properties of the mix were evaluated, usually by visual inspection, and any changes that needed to be made were incorporated into the second half of the mix. The balance of the constituents of the mix was added and the full batch mixed for an additional five minutes. In most instances no changes needed to be made and in the instances where changes were made they were made in such a way as to maintain a given water-cement ratio. The ratio of fine to coarse aggregates was adjusted so as to produce a workable mix that could be placed using an immersion type vibrator in a concrete wall that contained a moderate amount of reinforcement. Equal amounts of #4 to $\frac{1}{2}$ " and $\frac{1}{2}$ " to $\frac{3}{4}$ " coarse aggregate were used in the mix. The low water to cement ratio concrete mixes were made first and then when going to higher water to cement ratios the usual procedure is to replace the cement with the fine aggregate.

The mix description is given in Table 1. The plastic concrete was discharged into a wheelbarrow. Prior to testing the plastic concrete, the contents of the wheelbarrow were remixed with a shovel.

4. Testing of the Plastic Concrete.

The concrete after remixing with a shovel was simultaneously tested for slump, air content and unit weight. Vibration using a poker type vibrator was used to consolidate the concrete for the air content and unit weight as well as for the cylinders and test specimens. The temperature of the concrete was measured using a steel jacketed thermometer. The properties of the plastic concrete are recorded in Table 2.

5. Testing of the Hardened Concrete.

The unit weight of the six inch diameter concrete cylinders was measured and recorded in Table 3.

Using the unit weight of the concrete and the batch proportions, the mix proportions per cubic yard were calculated and are recorded in Table 4. All weights of aggregates are given in a saturated surface-dry condition.

The compression strengths at twenty-eight days are recorded in Table 5. Table 6 lists the modulus of elasticity of the concrete as determined by the ASTM 469-65 test at 28 days. At the end of 90 days moist curing the remaining concrete cylinders and prisms were taken out of the moist curing room.

The prisms were shipped to Eastport Maine on December 1. Two cylinders from each mix were tested for compression strength and the results are record in Table 5. All remaining cylinders were shipped to Ottawa in December.

APPENDIX "A"

Work Statement

Program A - The concrete mixes of Program A shall be made using a water-Cement + Fly ash) ratio of 0.40 ± 0.02 .

Mix Series A - In this series, five concrete mixes shall be made as follows:

- Mix 1 - control - CSA Type 10 cement
- 2 - repeat of mix No. 1
- 3 - repeat of mix No. 1.
- 4 - incorporating 25% fly ash and CSA Type 10 cement
- 5 - repeat of Mix No. 4
- 6 - repeat of Mix No. 4

From Mix Nos. 1,2,4, and 5, one 12 x 12 x 36-in prism and four 6 x 12-in cylinders will be cast. From Mix Nos. 3 and 6, sixteen 6 x 12-in cylinders will be cast. Before casting, properties of fresh concrete such as temperature, slump, unit weight and air content will be determined.

Densities of hardened concrete shall be taken at one day. All specimens shall be moist-cured until required for testing or for transportation to Treat Island or CANMET. A minimum curing period shall be 90 days before transporting test specimens to Treat Island.

At 28 days and before transportation to Treat Island or CANMET, two specimens from each mix shall be tested in compression; for mix Nos. 3 and 6, the 28-day specimens shall also be used for the determination of Young's static modulus of elasticity. Following a minimum curing of 90 days, the test prisms shall be transported to Treat Island by trucks and the remaining test cylinders shall be shipped to CANMET for long-term strength studies.

Mix Series B - In this series, two concrete mixes shall be made as follows:

- Mix 7 - Control CSA Type 50
- 8 - repeat of Mix No. 7.

From Mix No. 7, one 12 x 12 x 36-in prism and four 6 x 12-in cylinders will be cast. From Mix No. 8, sixteen 6 x 12-in cylinders will be cast. Preparation of the mixes, testing and shipping of the specimens shall be as in Series A (Mix Nos. 1 and 3).

Program B - Program A shall be repeated using a water/(cement + fly ash) ratio of 0.50 ± 0.02 .

Program C - Program A shall be repeated using a water/(cement + fly ash) ratio of 0.6 ± 0.02 .

Materials - All materials shall be provided by the contractor.

- (i) Cements Type 10 and Type 50 shall be purchased by the contractor;
- (ii) Fly ash shall be purchased from the Nova Scotia Hydro (Lingan Plant)
- (iii) Limestone aggregate shall be used and shall be obtained from a local producer in N. B. Maximum size shall be 3/4 in. and aggregates shall meet the requirements of CSA A23.1.
- (iv) Sulphonated hydrocarbon type A.E.A. shall be used.

Mix Proportioning Requirements - All mixes shall be proportioned to have a slump of 3 ± 1 " and an air content of 6 ± 1 per cent. Fly ash shall be incorporated in the mix as a direct replacement by weight of cement.

Completion Date For Laboratory Work - November 1, 1981.

APPENDIX "B"

TABLE 1B

% Passing

<u>SIEVE SIZE</u>	<u>FINE AGGREGATE BLAGDON PIT</u>	<u>COARSE AGGREGATE BROOKVILLE PIT</u>	
		<u>#4 - $\frac{1}{2}$</u>	<u>$\frac{1}{2}$ - $\frac{3}{4}$</u>
1		100	100
$\frac{3}{4}$		100	99
$\frac{1}{2}$		80	24
$\frac{3}{8}$		30	1
4	100	0	0
8	86		
16	65		
30	42		
50	21		
100	6		

APPENDIX "B"

TABLE 1B
% Passing

<u>SIEVE SIZE</u>	<u>FINE AGGREGATE BLAGDON PIT</u>	<u>COARSE AGGREGATE BROOKVILLE PIT</u>	
		<u>#4 - $\frac{1}{2}$</u>	<u>$\frac{1}{2}$ - $\frac{3}{4}$</u>
1		100	100
3/4		100	99
1/2		89	24
3/8		30	1
4	100	0	0
8	86		
16	65		
30	42		
50	21		
100	6		
Par			

TABLE I
CONCRETE MIX DESCRIPTION

<u>SERIES</u>	<u>% FLY ASH</u>	<u>% SLAG</u>	<u>CEMENT TYPE</u>	<u>WATER TO CEMENT RATIO</u>
J01	-		10	0.40 $\pm$ 0.02
2	-		10	"
3	-		10	"
4	25%		10	"
5	25%		10	"
6	25%		10	"
7	-		50	"
8	-		50	"
K01	-		10	0.50 $\pm$.02
2	-		10	"
3	-		10	"
4	25%		10	"
5	25%		10	"
6	25%		10	"
7	-		50	"
8	-		50	"
L01	-		10	0.60 $\pm$.02
2	-		10	"
3	-		10	"
4	25%		10	"
5	25%		10	"
6	25%		10	"
7	-		50	"
8	-		50	"

TABLE III
UNIT WEIGHT (LB/CU. FT.)

<u>CYLINDER NO.</u>	<u>UNIT WT.</u>	<u>CYLINDER NO.</u>	<u>UNIT WT.</u>	<u>CYLINDER NO.</u>	<u>UNIT WT.</u>
J01-1	145.1	J04-1	141.2	J07-1	149.1
2	145.7	2	143.0	2	148.4
3	144.9	3	142.3	3	149.1
4	145.2	4	141.6	4	147.6
J02-1	145.2	J05-1	144.4	J08-1	146.5
2	144.3	2	144.1	2	145.9
3	144.4	3	144.7	3	145.1
4	145.2	4	144.2	4	145.4
J03-1	146.6	J06-1	148.1	5	146.3
2	146.0	2	147.6	6	145.9
3	146.9	3	147.2	7	146.6
4	146.5	4	147.5	8	146.2
5	146.4	5	147.7	9	146.7
6	145.4	6	147.3	10	144.9
7	146.5	7	147.6	11	145.8
8	146.7	8	147.1	12	145.7
9	146.5	9	148.1	13	146.1
10	146.3	10	147.4	14	145.1
11	146.2	11	146.9	15	146.0
12	145.8	12	146.6	16	145.5
13	146.1	13	147.7		
14	145.8	14	147.9		
15	146.0	15	148.0		
16	146.3	16	144.8		

TABLE II

SERIES	DATE CAST	PROPERTIES OF PLASTIC CONCRETE			
		SLUMP (INCHES)	AIR CONTENT %	UNIT WT. (Lb/Cu. Ft.)	CONCRETE TEMP (°C)
J01	810815	3 5/8	6.6	145.6	24.0
2	"	3 1/4	6.6	145.6	23.0
3	"	3	5.5	146.4	23.5
4	"	4	7.0	141.3	23.0
5	"	3 1/8	6.8	144.5	23.0
6	"	2 7/8	5.3	147.6	23.5
7	810905	3 1/8	5.0	151.0	24.0
8	"	3 1/4	6.0	148.4	23.0
K01	810822	3	5.5	148.0	25.0
2	"	3 1/8	6.2	147.2	24.0
3	"	3 3/8	6.2	146.8	23.0
4	"	2 3/4	5.2	147.5	23.5
5	"	2 1/2	6.1	147.0	23.0
6	"	2 3/4	7.0	146.0	23.0
7	810905	3 3/4	6.0	148.7	23.0
8	"	2 3/4	5.5	149.3	23.0
L01	810828	3	6.0	147.9	22.0
2	"	4.0	6.0	147.2	22.0
3	"	3 1/2	6.0	147.4	21.0
4	"	3 1/8	6.1	147.3	21.0
5	"	2 1/2	5.8	148.6	21.0
6	"	2 3/4	6.1	149.0	21.0
7	810905	2 1/2	5.3	150.4	23.0
8	"	2 7/8	6.1	148.9	23.0

TABLE III
UNIT WEIGHT (LB/CU. FT.)

<u>CYLINDER NO.</u>	<u>UNIT WT.</u>	<u>CYLINDER NO.</u>	<u>UNIT WT.</u>	<u>CYLINDER NO.</u>	<u>UNIT NO.</u>
K01-1	145.8	K04-1	147.1	K07-1	145.4
2	146.0	2	145.9	2	145.0
3	146.0	3	147.2	3	144.5
4	145.8	4	147.4	4	145.0
K02-1	146.5	K05-1	146.2	J08-1	146.2
2	145.6	2	146.7	2	148.0
3	146.4	3	145.4	3	149.0
4	145.8	4	145.0	4	145.4
K03-1	145.8	K06-1	143.9	5	146.4
2	145.6	2	143.8	6	147.7
3	146.7	3	144.8	7	146.3
4	146.3	4	143.8	8	145.5
5	146.2	5	144.2	9	147.7
6	145.7	6	144.0	10	147.4
7	146.5	7	143.4	11	146.4
8	145.0	8	143.4	12	147.5
9	145.7	9	145.8	13	147.0
10	145.6	10	144.6	14	146.7
11	146.2	11	144.3	15	147.2
12	145.5	12	144.3	16	146.4
13	146.2	13	143.3		
14	145.7	14	144.3		
15	145.3	15	143.8		
16	144.9	16	144.5		

TABLE III
UNIT WEIGHT (LB/CU. FT.)

<u>CYLINDER NO.</u>	<u>UNIT WT.</u>	<u>CYLINDER NO.</u>	<u>UNIT WT.</u>	<u>CYLINDER NO.</u>	<u>UNIT WT.</u>
L01-1	146.1	L04-1	145.0	L07-1	146.3
2	146.7	2	145.6	2	147.0
3	146.5	3	144.0	3	146.1
4	144.9	4	144.9	4	145.6
L02-1	145.1	L05-1	145.7	L08-1	145.8
2	145.4	2	145.5	2	145.6
3	145.1	3	146.2	3	146.2
4	144.5	4	146.0	4	146.0
L03-1	146.2	L06-1	146.7	5	146.1
2	145.7	2	146.1	6	145.7
3	144.9	3	147.2	7	145.1
4	146.0	4	146.5	8	146.5
5	146.6	5	146.8	9	145.8
6	146.0	6	147.2	10	145.3
7	145.8	7	145.7	11	146.4
8	145.7	8	146.7	12	146.8
9	146.2	9	146.6	13	145.7
10	145.7	10	146.8	14	147.1
11	145.4	11	146.4	15	145.5
12	145.9	12	146.8	16	145.2
13	145.4	13	146.6		
14	145.2	14	146.3		
15	145.4	15	146.5		
16	145.8	16	146.8		

TABLE IV

MIX PROPORTIONS

Mix Proportions in Lb/Cu. Yd.							A/E Agent in oz./100 Lbs. of Cement
<u>MIX</u>	<u>CEMENT</u>	<u>FLY ASH</u>	<u>SLAG</u>	<u>WATER</u>	<u>F.A.</u>	<u>C.A.</u>	
J01	741	-	-	300	988	1902	1.51
2	741	-	-	300	988	1902	1.37
3	745	-	-	301	993	1912	1.25
4	536	179	-	286	892	1922	3.14
5	514	171	-	274	854	2088	2.69
6	538	179	-	286	894	2088	2.38
7	723	-	-	289	1019	2046	1.37
8	698	-	-	279	1057	1974	1.65
K01	586	-	-	294	1077	2041	1.41
2	583	-	-	291	1071	2030	1.54
3	581	-	-	291	1068	2024	1.51
4	412	137	-	274	1054	2105	2.55
5	404	135	-	269	1065	2096	2.95
6	406	135	-	270	1049	2084	2.89
7	525	-	-	263	1159	2066	1.73
8	505	-	-	253	1172	2100	1.73
L01	444	-	-	268	1230	2051	1.39
2	438	-	-	270	1242	2025	1.39
3	442	-	-	266	1232	2039	1.39
4	309	103	-	250	1251	2065	2.78
5	310	103	-	251	1281	2067	2.78
6	313	104	-	250	1265	2089	2.78
7	412	-	-	248	1309	2092	1.67
8	408	-	-	246	1296	2072	1.89

TABLE V
COMPRESSIVE STRENGTH

28 Days

<u>CYLINDER NUMBER</u>	<u>COMPRESSIVE STRENGTH IN psi</u>	<u>CYLINDER NUMBER</u>	<u>COMPRESSIVE STRENGTH IN psi</u>	<u>CYLINDER NUMBER</u>	<u>COMPRESSIVE STRENGTH IN psi</u>
J1-1	5144	K1-1	4504	L1-1	3892
J1-2	5504	K1-2	4435	L1-2	3901
J2-1	4702	K2-1	4098	L2-1	3322
J2-2	5042	K2-2	4562	L2-2	3431
J3-1	5738	K3-1	4597	L3-1	3372
J3-2	4524	K3-2	4303	L3-2	3578
J4-1	4407	K4-1	4490	L4-1	2915
J4-2	4622	K4-2	4226	L4-2	3011
J5-1	4678	K5-1	3596	L5-1	2375
J5-2	4417	K5-2	3892	L5-2	3117
J6-1	4965	K6-1	3457	L6-1	3096
J6-2	4984	K6-2	3606	L6-2	3130
J7-1	6134	K7-1	4289	L7-1	3571
J7-2	5452	K7-2	4293	L7-2	3654
J8-1	6038	K8-1	3833	L8-1	3390
J8-2	5238	K8-2	4129	L8-2	3486

TABLE V Cont'd

COMPRESSIVE STRENGTH

90 DAYS

<u>CYLINDER NUMBER</u>	<u>COMPRESSIVE STRENGTH IN psi</u>	<u>CYLINDER NUMBER</u>	<u>COMPRESSIVE STRENGTH IN psi</u>	<u>CYLINDER NUMBER</u>	<u>COMPRESSIVE STRENGTH IN psi</u>
J1-3	5763	K1-3	3130	L1-3	4167
J1-4	5392	K1-4	5074	L1-4	4261
J2-3	6334	K2-3	4848	L2-3	3795
J2-4	5777	K2-4	4980	L2-4	4160
J3-3	6239	K3-3	5158	L3-3	3316
J3-4	6126	K3-4	5168	L3-4	4157
J4-3	4800	K4-3	5392	L4-3	3547
J4-4	5354	K4-4	5685	L4-4	3617
J5-3	5579	K5-3	4968	L5-3	3920
J5-4	5433	K5-4	4783	L5-4	3456
J6-3	5734	K6-3	4505	L6-3	3869
J6-4	6024	K6-4	3469	L6-4	3896
J7-3	7125	K7-3	4664	L7-3	3930
J7-4	6496	K7-4	4845	L7-4	4100
J8-3	5819	K8-3	4919	L8-3	3731
J8-4	6085	K8-4	4880	L8-4	2773

TABLE VI
MODULES OF ELASTICITY

<u>CYLINDER NO.</u>	<u>AGE DAYS</u>	<u>MODULES OF ELASTICITY IN psi x 10³</u>
J3-1	30	5633
J3-2	30	4953
J6-1	30	5223
J6-2	30	4944
J8-1	28	5121
J8-2	28	4863
K3-1	29	4802
K3-2	29	4696
K6-1	29	4120
K6-2	29	4181
K8-1	28	4302
K8-2	28	4807
L3-1	31	4337
L3-2	31	4277
L6-1	31	4212
L6-2	31	4344
L8-1	28	4086
L8-2	28	4091